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Synthetic vision system for improving unmanned aerial vehicle operator situation awareness

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ABSTRACT

The Air Force Research Laboratory's Human Effectiveness Directorate (AFRL/HE) supports research addressing human factors associated with Unmanned Aerial Vehicle (UAV) operator control stations. Recent research, in collaboration with Rapid Imaging Software, Inc., has focused on determining the value of combining synthetic vision data with live camera video presented on a UAV control station display. Information is constructed from databases (e.g., terrain, cultural features, pre-mission plan, etc.), as well as numerous information updates via networked communication with other sources (e.g., weather, intel). This information is overlaid conformal, in real time, onto the dynamic camera video image display presented to operators. Synthetic vision overlay technology is expected to improve operator situation awareness by highlighting key spatial information elements of interest directly onto the video image, such as threat locations, expected locations of targets, landmarks, emergency airfields, etc. Also, it may help maintain an operator's situation awareness during periods of video datalink degradation/dropout and when operating in conditions of poor visibility. Additionally, this technology may serve as an intuitive means of distributed communications between geographically separated users. This paper discusses the tailoring of synthetic overlay technology for several UAV applications. Pertinent human factors issues are detailed, as well as the usability, simulation, and flight test evaluations required to determine how best to combine synthetic visual data with live camera video presented on a ground control station display and validate that a synthetic vision system is beneficial for UAV applications.

Keywords: synthetic vision, conformal overlay, situation awareness, unmanned aerial vehicle, UAV

1. OVERVIEW

Unmanned Aerial Vehicles (UAVs) are aircraft without the onboard presence of a pilot or crew. Though the physical separation of the crew from the aircraft offers many promising benefits, it also presents challenges to the effective design of the UAV control station. Numerous human factors issues such as system time delays, poor crew coordination, high workload, and reduced situational awareness may negatively affect mission performance [1]. When onboard an aircraft, a pilot and crew receive a rich supply of multi-sensory information instantaneously regarding their surrounding environment. UAV operators, however, may be limited to a time-delayed, reduced stream of sensory feedback delivered almost exclusively through the visual channel.

Of all the information displays within military UAV control stations, the video imagery from various cameras mounted on the UAV is particularly valuable. UAV pilots use imagery from the nose and gimbal cameras to verify clear path for taxi/runway operations, scan for other air traffic in the area, and identify navigational landmarks and potential obstructions. Additionally, sensor operators use imagery from a gimbal-mounted camera to conduct a wide variety of intelligence, surveillance and reconnaissance activities as well as to directly support combat operations. However, video imagery quality can be compromised by narrow camera field-of-view, datalink degradations, poor environmental conditions (e.g., dawn/dusk/night, adverse weather, variable clouds), bandwidth limitations, or a highly cluttered visual scene (e.g., in urban areas or mountainous terrain). If imagery interpretation could be enhanced and made more robust under a wide variety of situations, UAV mission effectiveness is expected to increase substantially.

Synthetic vision systems can potentially ameliorate negative video characteristics and enhance UAV operator interpretation of the imagery. Spatially-relevant information is constructed from databases (e.g., terrain, cultural features, maps, etc.) as well as numerous real-time information updates via networked communication with

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other sources (e.g. intelligence assets, C2 sources, etc.) and overlaid conformal onto the dynamic camera image display. These computer-generated overlays appear to 'co-exist' with real objects in the imagery, highlighting those points and regions of interest to operators. Those familiar with virtual reality technology will know of this concept as 'augmented reality'[2]. This synthetic vision overlay is hypothesized to have many benefits. It may improve operator situation awareness by highlighting information elements of interest on the camera image, such as threat location, the expected location of targets, landmarks, emergency airfields, and position of friendly forces. Secondly, it may maintain the operator's situation awareness of an environment if the video datalink is temporarily degraded or lost.

Synthetic vision systems can also serve to facilitate intuitive networked communications between geographically separated users. One concept is to have 'on command' representation of friendly, neutral, and hostile forces using synthetic overlays, allowing the UAV operator to look around and "see" those around him/her. Friendly forces, networked in some manner, could share information on their past and present positions, as well as planned paths and possibly their action points, facilitating team interaction. The friendly forces could also pool their knowledge of neutral and hostile forces to help maintain battlespace awareness. Conceptually, the synthetic vision system can display things that cannot normally be seen. For example, perhaps the state of a system can be portrayed based on its emissions (e.g., radar), or machine-to-machine communications (e.g., data link activity) can be highlighted when data is being sent/received. By representing the activities and states, the operator may be able to gain additional situation awareness about the surrounding systems.

This paper describes an ongoing collaboration between Rapid Imaging Software Inc. and the Air Force Research Laboratory's (AFRL) Warfighter Interface Division in tailoring and evaluating a synthetic vision system for UAV applications. Related human factors issues will be delineated and discussed. An overview will then be provided of an AFRL research program that is evaluating the benefits of synthetic vision technology for UAV applications and developing human factors guidelines associated with this technology.

2. COLLABORATION ON CANDIDATE UAV SYNTHETIC VISION SYSTEM

The Air Force Research Laboratory's Warfighter Interface Division has engaged in an undertaking to design and evaluate the military utility of conformal interactive synthetic vision overlay concepts tailored to UAV operations. Using detailed knowledge of current Air Force UAV operations along with established human factors design practices, several initial interface concepts have been generated and supporting hardware architecture developed. In parallel, Rapid Imaging Software, Inc., under a NASA research contract, has developed a synthetic vision product called the SmartCam3D System (SCS) to improve the situation awareness of NASA UAV operators. The SCS has been engineered to be tested in operational UAV environments and has been evaluated by operators during multiple flights of the NASA X-38 UAV and the Army Shadow UAV. The present collaboration brings these two resources together to design and evaluate tailored synthetic visual overlays for various Air Force UAV and C2 applications, including those involving teleoperated and small UAV applications.

2.1 SmartCam3D Synthetic Vision System

The SmartCam3D (SCS) is an enhanced visualization technology developed by Rapid Imaging Software Inc. as part of a NASA X-38 RPV flight-test effort. Subsequently, it was matured during an integration effort for an Army UAV program. For the present effort, it has been tailored for Air Force UAV applications through collaboration with the AFRL. This system combines real-time synthetic vision with live video, in an attempt to enhance the situation awareness of UAV operators across a wide range of missions and environmental conditions (Figure 1). This technology provides the users with real-time video that is enriched with conformal spatially-relevant scene information from multiple sources (database, mission plan, real-time intel updates, etc.). The goal is to effectively increase the signal-to-noise ratio of the imagery, allowing operators to more quickly locate, identify, and act on critical information.

The SCS consists of three physical components: the UAV platform, a camera which produces a video image stream, and a computer (PC or laptop) with the SCS software to create a synthetic vision which matches the camera (Figure 2). The SCS computer is stationed in the control station and has a geographic database that the software uses to create the synthetic view. Additional network feeds are needed to provide SCS with real-time intelligence and C2 updates. The notion of SCS is simple. A video camera is mounted on the aircraft in such a manner as to provide the operator with a view from the vehicle. At the same time, a computer creates a three-dimensional representation of the current scene that the camera should be viewing. Doing this requires a camera bore-sight calibration procedure to co-align the real and simulated cameras. This done, the two streams of video are overlaid inside of the computer.

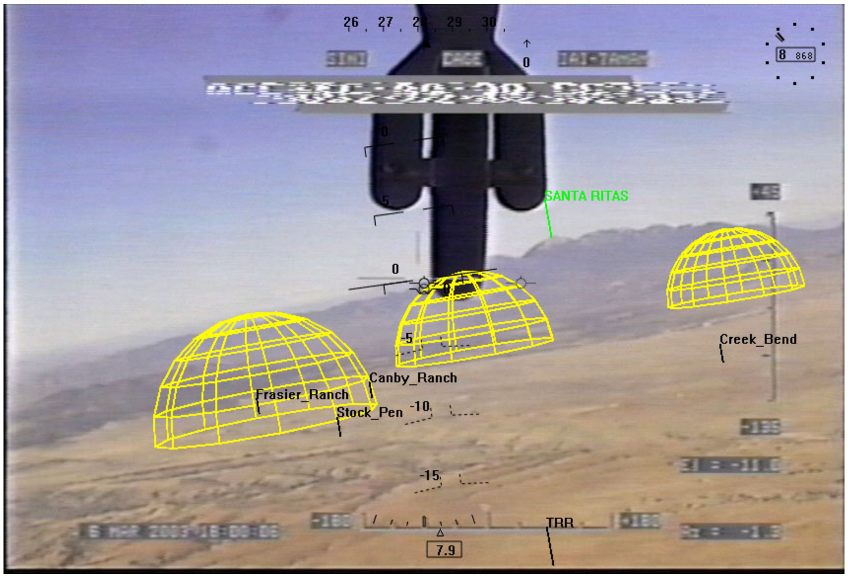

Figure 1. SmartCam3D (SCS) display illustrating spatially referenced computer-generated overlay symbology onto real-time video imagery.

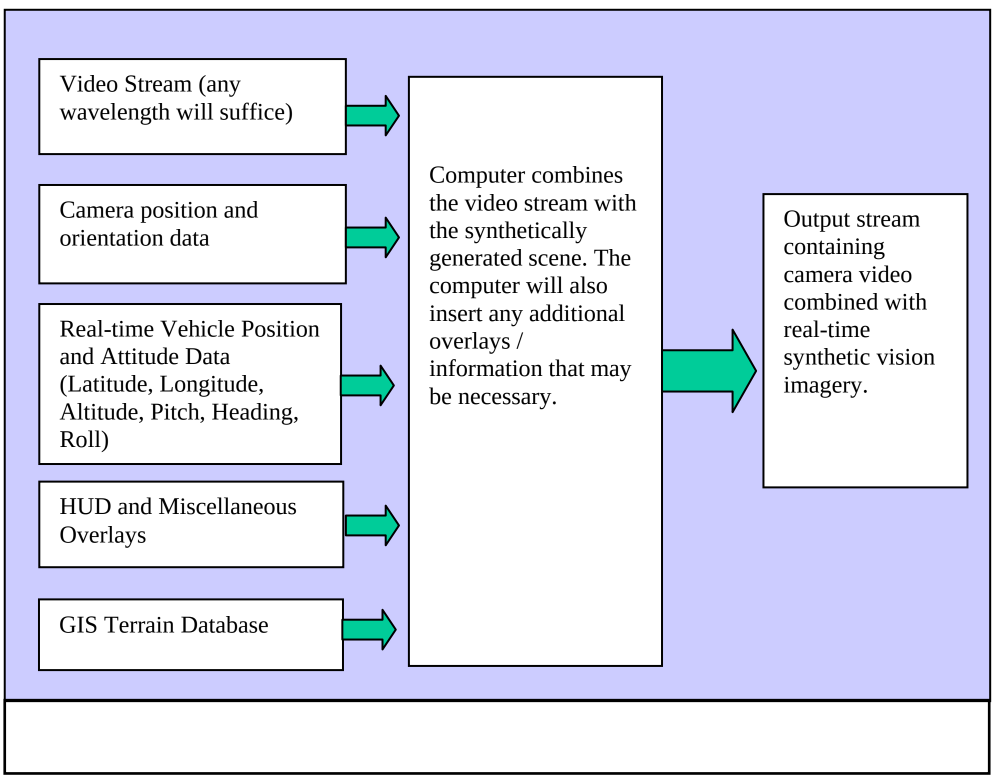

Figure 2. Basic components of the SmartCam3D System (SCS).

Another critical component for the SCS operation is a real-time video stream and position/attitude data for the aircraft. The specific data that is required includes: latitude, longitude, altitude, pitch, heading and roll. Additionally, if the camera is mounted on a gimbal and has zoom capability, then gimbal angles and zoom settings are also required in the data stream. Realistic performance requires high data rates (i.e., greater than once per second). This data allows the software to synthesize a real-time synthetic scene to match the camera's view.

Symbology on the SCS is based on information inserted by the computer that details the location of landing zones, no-fly zones, runways, obstructions, buildings, topography and other geographic data. Anything with known geographic coordinates can be included in the scene. Since the synthetic vision system is based on the VisualFlight software (www.visualflight.com), which is already compatible with most NIMA (National Imagery & Mapping Agency) data formats (DTED, ADRG, CADRG, CIB, etc.), the necessary geographic data is readily available. This synthetic scene is overlaid on the video in real time, and matches the camera view. As the vehicle flies, operators can look at the live video and see the target or landing locations overlaid with the synthetic view. In cases of night, poor weather or other limited visibility environments, the operators can utilize the computer-generated synthetic camera imagery (essentially 're-creating' modeled components of the real world scene via computer graphics). However, if video imagery is available, it can provide a view that includes transient objects that are not present in the geographic database. Obstructions and hazardous areas can be clearly marked, as can important landmarks and desired landing points. Furthermore, because the synthetically created objects are generated from digital data, they are not subject to the limitations of visibility inherent to video. While darkness, terrain occlusion, smoke, fog, icing, and haze all impact the video, the synthetically generated scene remains unobstructed.

2.2 Example Synthetic Vision Overlay Interface Concepts for UAV Applications

Candidate interface concepts were generated for teleoperated UAV applications (examples are depicted in Figures 3-6). These concepts are a result of the AFRL/Rapid Imaging, Inc. collaboration effort, along with the results of a usability analysis conducted with UAV operators (see section 4.1). Validation of these concepts in high fidelity simulation and flight tests is underway (see sections 4.2 and 4.3). Even though this validation process has not been completed, the display concepts are introduced here to make the follow on discussion of human factors issues more relevant.

Figure 3. Synthetic vision symbology added to simulated UAV gimbal video imagery (symbology marking threat, landmarks, areas of interest and runway).

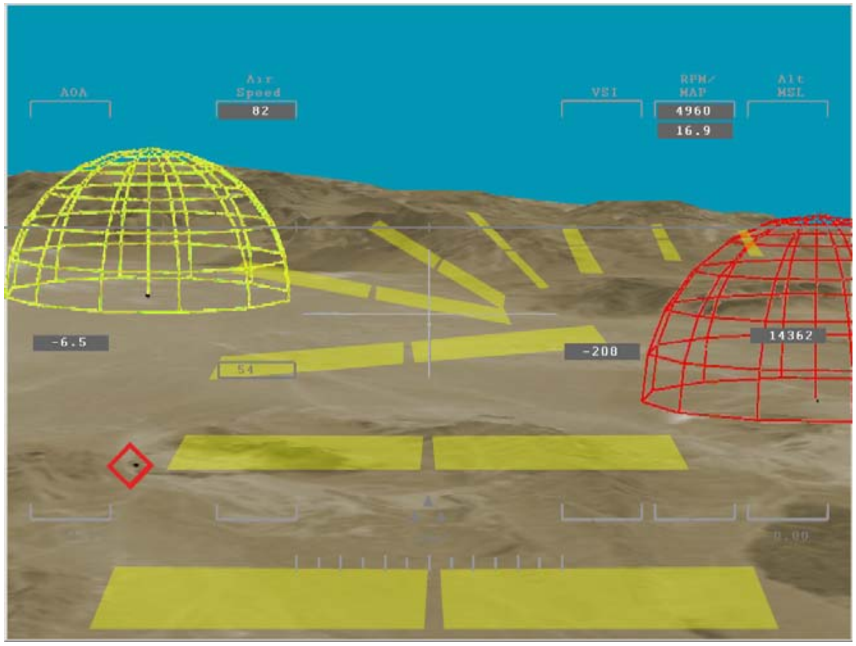

Figure 4. Synthetic vision symbology added to simulated UAV nose camera video imagery (symbology marking threats and planned vehicle pathway).

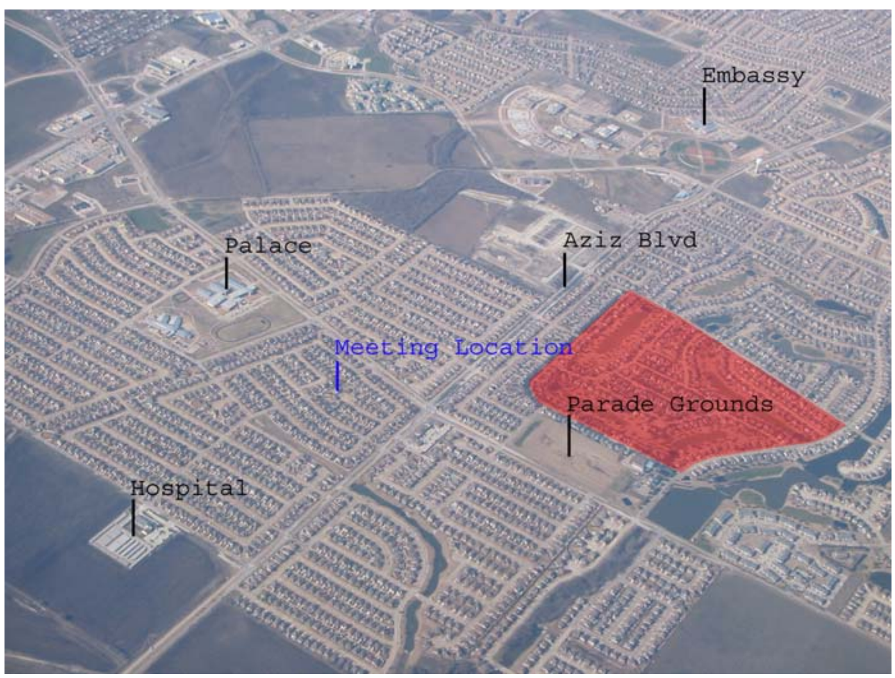

Figure 5. Synthetic vision symbology for improving situation awareness in cluttered urban environments.

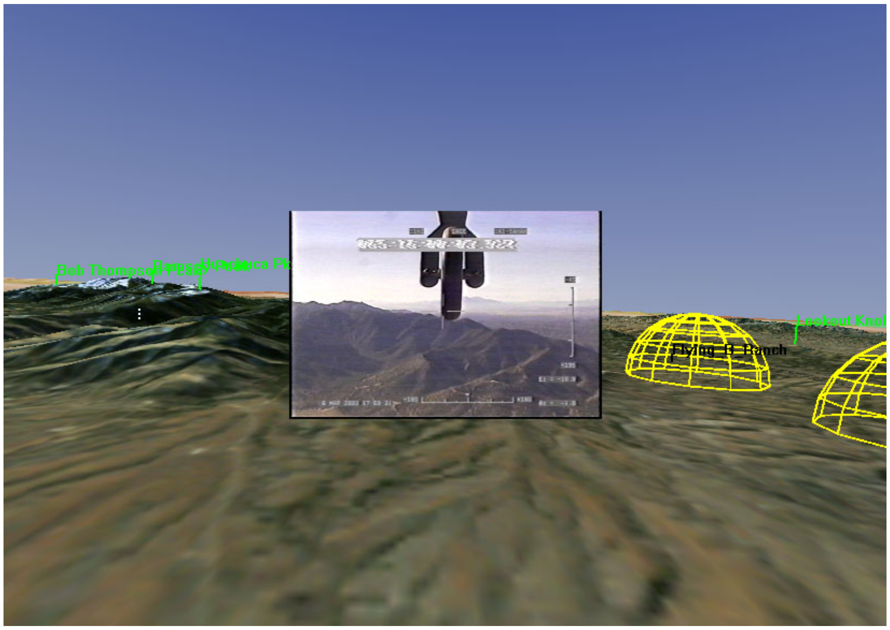

Figure 6. Picture-in-picture concept, with real video imagery surrounded by synthetic-generated terrain imagery. Affords virtual expansion of the available sensor field-of-view well beyond the physical limits of the camera.

3. HUMAN FACTORS ISSUES WITH UAV SYNTHETIC VISION SYSTEMS

Synthetic vision systems consists of computer-generated 'worlds' created solely from various models and databases. Presenting computer based information in a conformal manner with sensor imagery on a unified display has been demonstrated in past research to reduce scanning time, reduce the need to mentally integrate spatial information from disparate sources, and facilitate attentional focus and management[3]. It is thought that the performance benefit is a result of the synthetic vision system highlighting important information elements. Also, the system can include information that does not have a correlate in the actual sensor imagery, such as threat lethality envelopes. Past research has primarily focused on using synthetic vision systems to help piloting tasks during low-level flights with manned platforms[4]. The system can convey self-motion cues and depth cues without occluding the sensor image. Moreover, flight guidance symbology can be provided for reduced visibility conditions, especially during terminal flight operations such as landings. It is anticipated that a synthetic vision system's highlighting would have similar benefits for UAV flight operations. Additionally, ground target search and identification tasks associated with many UAV missions will likely benefit from this technology. However, there are numerous human factors issues (described below) to consider for UAV applications of synthetic vision systems.

3.1 Location of synthetic vision symbology

One major design consideration is the location of the synthetic vision symbology: overlaid on the existing camera display, on a head coupled head-mounted display (HMD), or a separate dedicated display on the console. Although head-coupled applications afford the potential to allow full 360 degree viewing of an area, previous simulation research has demonstrated that use of a HMD can be detrimental to many UAV sensor operator tasks[5]. The use of separate displays reduces clutter on the sensor imagery, however previous research has shown that the scanning time involved in using a separate display is often more costly than the additional clutter imposed in overlaying synthetic vision onto the existing sensor imagery display[6]. Having the information overlaid conformally on the camera display may reduce scan time, minimize division of attention, and may improve information retrieval, but with the potential cost of additional clutter and the possibility of cognitive tunneling (explained further below). This research issue also involves determining how information on the head-up displays should correspond to head-down displays. The concept is to maintain visual momentum as the individual shifts attention from head-down to head-up or vice versa.

3.2 Presentation of synthetic vision symbology: scene-linked or not.

Assuming that the synthetic vision symbology is to be overlaid on the sensor image rather than presented on a separate display, it needs to be determined *how* the symbology will be presented simultaneously with the sensor image. Specifically, will the symbology elements just be superimposed over the sensor image or will elements also be “scene-linked” (referenced to the world) such that they undergo the same visual transformation as real objects depicted in the imagery? An example of the latter is a virtual “billboard” growing larger as the operator approaches the runway and any pitch or yaw of the aircraft would be perceived incidentally when viewing the display. The choice of presentation method may be symbology element specific. One driving factor is the degree to which the UAV display is anticipated to be cluttered — if there are numerous items in short range, it may not be feasible to have them all increase in size as the operator closes in. However, scene-linking symbology to elements in the real image may reinforce other motion cues and benefit information retrieval (see 3.6).

3.3 Optimization of the synthetic vision system symbology

3.3.1 Individual synthetic vision symbology elements. For every display element, there are a multitude of related human factors issues. For instance, for each line segment and icon used, what is the ideal shape, color, brightness, contrast, size, thickness, style, etc.? What is the ideal font size, color, background, etc. for any label used? To what degree of detail should the labels provide information? Should the transparency of the symbology be manipulated such that both the video imagery and the synthetic vision symbology are simultaneously visible? Should color and size vary based upon visual conditions? For certain types of symbols, additional design questions arise. With ‘pathway-in-the-sky’ formats, for example, the appropriate number of pathway segments needs to be determined, along with their spacing. Finally, usability of the candidate symbology elements needs to be evaluated. For this testing, the symbology should be tested with a sensor image that replicates the anticipated background, sensor view, clutter, light level, etc. that will appear in operational applications.

3.3.2 Terrain overlay. There are a variety of methods that can be employed to portray terrain in a synthetic vision display, including a simple “gridded overlay” (rectangular grids of known size to facilitate depth perception), terrain texturing (e.g., colors correspond to different absolute terrain elevations), and photo-realistic terrain imagery (i.e., from satellite imagery data). Various maps and other geographically referenced overlays may also be useful depending on the task at hand (e.g., FalconView; http://www.falconview.org/overview.htm). Once again, usability of the candidate terrain overlay needs to be evaluated in representative UAV environments.

3.2.3 Picture-in-picture (PIP) presentation. The symbology elements and terrain overlay mentioned above play a key role in the implementation of the PIP concept. With PIP, the video image is condensed such that it only takes up a portion of the display width so that a synthetic view can be presented surrounding the video image, thereby virtually increasing the overall field-of-view available to the operator. In implementing the PIP concept, several unique design questions arise: Should the location of the sensor imagery be fixed in the center of the display, or should the operator be able to adjust its location? Should the operator be able to pan the field-of-view presented on the PIP? How many size ratios (synthetic scene/camera image) should be made available to the UAV operator and should the operator’s size selection be continuous or discrete, the latter involving selection between pre-established ratios? An ongoing simulation evaluation (see section 4.2) is addressing these issues along with an even more fundamental design question: does the PIP concept improve situation awareness and target prosecution?

3.4 Information clutter

The ability to provide a synthetic vision system overlaid on a sensor image can have both a positive and negative impact[7,8]. Having all the information on one display can minimize scanning and the effort required to access and monitor all the elements. However, the information clutter may inhibit the processing of the fine detail in the sensor imagery because of the inhibitory effects of overlay clutter. Moreover, the capability afforded by synthetic vision overlays to enable operators to ‘see’ data about objects that are not visible in the real sensor imagery can increase clutter. For example, with this “Superman X-ray Vision” a threat that is visually occluded behind a mountain might continue to be depicted with an overlaid symbol. However, with this portrayal, the operator can lose occlusion cues, which are important for perceiving depth. Presenting “occluded” objects with dotted or blurred outlines might help operators track where elements are located in the three-dimensional world. Thus, the design of the synthetic vision symbology needs to take into account the potentially negative effects of information clutter by only including elements that will benefit the operators' situation awareness and performance and employing design features that minimize clutter effects and confusion.

Regardless of the symbology set, operators should be provided with the capability to declutter the synthetic vision symbology. A declutter function is already provided in many UAV control stations to control the degree to which flight symbology is portrayed. A similar function can be applied to the synthetic vision system whereby the operator can control the amount of synthetic information portrayed. However, research is needed on how best to implement decluttering modes for different UAV applications. More 'global' levels of declutter may be optimal, whereby the operator can systematically select and deselect classes of information. For instance, perhaps only threat information is desired with no other synthetic information. Another approach would allow operators to de-select individual symbology elements, for instance, those that might be adjacent to a target that the operator needs to have an unobstructed view.

3.5 Information view management

Providing the operator with the ability to declutter the synthetic vision system symbology is one method of managing how information is presented. However, there are numerous other techniques for "view management" which maintain visual constraints on the projections of objects on the display[9]. With appropriate algorithms, the system can prevent objects from occluding each other, by modifying selected object properties such as position, size, and transparency. By making adjustments in the manner in which synthetic vision symbology is presented, problems with different synthetic elements occluding each other can be minimized as well as a synthetic element occluding a key element in the real sensor image. Likewise, an intelligent system can ensure that "distant text" does not become illegible and labels are automatically reoriented and repositioned based on the operator's viewpoint with respect to the object. Research is needed to identify the algorithms of highest utility for the task at hand.

Besides managing the view to optimize the visibility of the synthetic vision symbology, an intelligent system can highlight in some fashion when new synthetic elements appear that are critical for operator attention. Conversely, the capability to retrieve dated information might be useful, for instance to review past flight paths or conduct battle damage assessment. The system can also help the operator retain spatial context with respect to the overall situation by interpolating between old and new viewpoints over a transitional period of a few seconds, slowing down the rate of transition[10]. Evaluation is required to see if this is a benefit to spatial awareness, outweighing the costs of less responsive direct camera control. Identifying useful coding methods to indicate the criticality, urgency, and timeliness of information depicted by elements is another research topic.

3.6 Effect of synthetic vision symbology on retrieval of non-synthetic information.

Cognitive tunneling can occur when the operator becomes focused on an element of the synthetic vision symbology (or objects to which attention is directed by the synthetic symbology) to such an extent that other important objects or events in the sensor imagery are not attended[11]. In the case of UAVs, this may result in the operator not detecting unexpected, high-interest targets. Scene-linking the synthetic vision symbology may reduce the incidence of cognitive tunneling[12]. With scene-linking, the augmented information is integrated into the visual scene, rather than superimposed. It is thought that scene-linking helps by grouping the synthetic information and real sensor information into one perceptual group, thus reducing problems associated with attentional allocation. (This is based on object-based models of visual attention that postulate that complex scenes are parsed into groups of objects, with attention focused on only one object at a time, with object groups defined by contours, color, etc.[13]). However, increasing the amount of information presented via synthetic vision overlays could increase the risk of cognitive tunneling by the operator.

Cognitive tunneling is also an issue for the PIP display concept for synthetic vision systems. With PIP, real video imagery is surrounded by a synthetic view, thereby virtually increasing the field of view visible to the operator. There is past research evaluating the use of concurrent exocentric maps for improving localization performance. In this case, the embedded map was opaque, and the operator could pan the insert to see the view behind it[14]. It is not clear whether the PIP concept will constitute a different perceptual group, and thus promote cognitive tunneling. The fact that the surrounding view is an extension of the scene depicted within the PIP and that the PIP's transparency can be manipulated, may help perceptual grouping of the two scenes. Experimental evaluations are underway to determine this.

3.7 Blending of synthetic vision display and sensor image.

One advantage of a synthetic vision system is its potential to provide mission information when video datalink is degraded or the visibility is limited. At a maximum setting, the synthetic vision imagery could totally replace the sensor image, while other settings could specify a blending of the two information sources by changing the transparency of the entire synthetic vision symbology set. Research issues include determining suitable methods to invoke imagery blending (discrete steps versus continuous control) and which type of terrain overlay is most suitable for blending.

Blending techniques may be appropriate for individual symbology elements as well. For instance, gradual blending of the real and synthetic information along the edges of the object in the sensor image may help create a smooth transition between the synthetic and real objects at the points where occlusion occurs or there is an error in registration.

3.8 Distributed network collaborative communication of synthetic vision system information.

It is plausible that a synthetic vision system can play a key role in supporting distributive collaborative communication in the net-centric environment envisioned for the UAV domain. Besides providing a common operating picture of available battlespace information, one individual could mark a specific spatially referenced point of interest on a work station, causing duplicate informative synthetic symbology to appear on the displays of other geographically separated stations in the warfare network. Thus, the synthetic vision system can be applied both as a *display* and as a *control*. To date, little research has addressed the many issues associated with implementing such a capability. For instance, one question is how best to keep each network member informed on the status of a new designation – its source, status of coordination from others, timeliness, priority, etc. How should far off objects, beyond one's normal line-or-sight or off-boresight be represented? What methods are suitable for teamwork and planning?

3.9 Reliability of information.

Synthetic vision systems are based on data drawn from one or more data sources and the reliability, accuracy, and currency of that information will vary. Additionally, a source may be reliable for one type of information but less reliable for other information types. It may be useful for UAV operators to be able to drill down to obtain knowledge of the data source for specific elements, to help judge the veracity of the data. It may also be possible to implement algorithms that weight the reliability of information and portray the certainly level with some type of coding method.

3.10 Adequacy of the performance of the synthetic vision system.

Objects in the synthetic world and real world must be properly aligned (i.e., registered) with respect to each other on the display, or the illusion that the two worlds coexist will be compromised[15]. If registration errors are systematic, operators might be able to adapt. Indeed, that is one research question: How much registration error is tolerable for a UAV application before task performance degrades substantially? Likewise, how much time delay can an operator tolerate? The time delay discussed here refers to the time difference between the measurement of the position and orientation of the sensor viewpoint to the moment when the synthetic image corresponding to that position and orientation appears in the display. Delays can cause registration errors and reduce task performance. There are several points in the overall system that contribute to both time delay and registration error, as well as make it likely that the problems will be variable. Perhaps the most detrimental to the performance of a synthetic vision system is the update rate and accuracy of the flight data. The quality of the UAV positional data, for instance, is subject to quantization error, random delays, and basic measurement error, besides problems introduced by the telemetry system. Advances in prediction algorithm design may help overcome the limitations of imprecise and tardy data input to the synthetic vision system. Manual intervention should also be enabled whereby the operator can dynamically recalibrate the correspondence of the synthetic and real worlds.

3.10 Operator control of synthetic vision system functions.

The preceding subsections delineate many capabilities that could be implemented, along with the synthetic vision system, to allow the operator to modify the symbology, e.g., amount of symbology presented, characteristics of the picture-in-picture, and features of the distributed communication system. For each of these candidate functions, the ideal control interface needs to be specified. The UAV operators' conventional controllers (keyboard, mouse, bezel switches, and joysticks to control camera zoom and direction and UAV flight) need to be examined as to how best to integrate these additional control requirements. At AFRL, speech-based control is being considered whereby the operator's speech signals are used to carry out preset activities[16].

4. EVALUATION OF SYNTHETIC VISION SYSTEM FOR UAVS

The human factors issues raised in Section 3 demonstrate that there are many research questions relative to the application of synthetic vision systems to UAVs. What isn't reflected in this section is the potential interaction of variables. A candidate symbology concept may only be beneficial if clutter level is low, visibility is good, or there is minimal image motion. Or *individual* symbology concepts may show a benefit, but when they are implemented *together* in a system, operator performance degrades due to unacceptable clutter, etc. Additionally, many human factors guidelines will be application-specific. Thus, evaluations are needed that not only focus on specific research issues, but also evaluate the application of a total candidate synthetic vision system in several different UAV task environments. The end goal is to determine if the synthetic vision system will benefit UAV operations and result in increased mission effectiveness. This confirmation involves several different types of evaluations, described below, many of which can be performed in parallel.

4.1 Usability Evaluations

Evaluations employing usability engineering tools enable a rapid design/evaluation/iteration cycle to identify promising synthetic vision system symbology concepts for UAV applications. Such an evaluation was conducted as part of the AFRL/Rapid Imaging, Inc. collaborative effort[17]. With this process, the most promising candidate concepts were identified, taking into account operator 'profiles', 'use case scenarios' and function requirements. A critical design review of these concepts was then conducted with UAV operators, system developers, and human factors engineers, using a series of computer-generated illustrations of how the synthetic vision concepts would be implemented in the performance of the use-case scenario. This process was found to be very valuable in identifying the strengths and weaknesses of several specific symbology sets. The results of this usability evaluation are now being addressed in detail in simulation evaluations.

4.2 Simulation Evaluations

The UAV control station simulation facility at Wright-Patterson Air Force Base (Figure 7) is being used to support a series of evaluations to address many of the issues identified in Section 3, utilizing the most promising symbology concepts identified in the usability evaluation. The high fidelity simulation environment allows for the adequate control of experimental conditions, manipulation of variables not possible in operational flight tests, and use of scripted, off-nominal events that either occur infrequently or are unsafe to test in a real-world environment. Events such as camera slew error can be inserted into the simulation in a manner that allows for complete repeatability across trials. Specifically, these evaluations will help identify optimal control techniques for information display, resolve issues of display clutter, and identify those concepts that result in highest mission performance. For example, the objectives of a study currently underway are to determine whether use of symbology flagging landmark locations and the picture-in-picture concept will speed designation of known targets without impacting the detection of unexpected targets.

Figure 7. UAV sensor operator control station.

4.3 Flight Test Evaluations

Flight demonstrations and flight tests are required to demonstrate that the synthetic vision symbology can be successfully integrated with the UAV platforms being targeted and that the performance requirements (3.10) can adequately be met. Flight tests can also confirm results from simulation evaluation that indicate that the synthetic vision symbology improves operator performance and does not negatively impact any operator tasking. In other words, flight tests validate whether the synthetic vision system can be successfully utilized and is beneficial in the intended UAV environment.

An earlier version of the SmartCam3D synthetic vision system was successfully demonstrated on the NASA X-38 vehicle during flight testing. During one of the flights, a control problem resulted in an unexpected 180 degree roll. Because the synthetic vision system offered improved situation awareness, operators watching the SmartCam system became aware of the problem long before the flight test engineers, who had to glean something was amiss from a display of six rapidly changing numbers. Results from these flight tests, as well as subsequent integration and tests, provide further support for the utility of a synthetic vision system. For the candidate synthetic vision system resulting from this AFRL/Rapid Imaging, Inc. collaborative effort, planning for flight tests is underway. Additionally, the system has already been successfully integrated in a UAV ground control ground control station and favorable comments have been received from operators.

4.3 Summary

Synthetic vision system technology promises to enhance situation awareness for UAV operations, as well as decrease workload, improve network collaborative communication, and minimize effects of video datalink degradation. Operational benefits predicted include faster target acquisition and assessment, more targets serviced, and reduced potential for collateral damage. There are, however, numerous questions pertaining to the design, implementation, and integration of a synthetic vision system in UAV applications.

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